

Gamma Correction Only Gain/Offset Control System and Method for Display Controller

Background of the Invention

Field of the Invention

5 [0001] This invention relates generally to systems and methods for control of video displays. More particularly, this invention relates systems and methods that control of contrast and brightness of a video display.

Description of Related Art

[0002] Color video displays receive digital or analog signals that indicate the magnitude of the magnitude of the luminance of the primary colors employed by the display to create a color image. There are numerous standards that are known in the art that generate these signals for exciting materials within the display responsible for generating the light of the image. In cathode ray tubes (CRT), the light is emitted by phosphors deposited on a surface of the CRT. An electron gun is stimulated by the input analog signal to create the appropriate magnitude of emission of the light to create the color components of the image. In a liquid crystal display (LCD), a voltage is applied to a polymeric material which is twisted to cause polarization of light to be rotated. The level of the voltage determines the amount of rotation of the polarization and thus acts as to adjust the luminance of the light transfer through the LCD or reflected from the LCD. The standards for computer displays, as is known in the art, are

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particularly designed for use with CRT type displays and must be adapted for use with LCD displays.

[0003] Refer to Fig. 1 for a discussion of a circuit of the prior art employed to adapt a video signal to the necessary levels for driving an LCD panel. The video signal **5** is the analog voltage level indicating the luminance level that the display is to emit. The video signal **5** is received by a digital to analog-to-digital converter **10** and converted to a sampled digital number indicating the magnitude of the voltage of the video signal **5**. The sampled digital value of the video signal is transferred from the analog-to-digital converter **10** to a scaling circuit **15**. The scaling circuit **15** adjusts or normalizes the digital value of the video signal such that the range of the video signal encompasses the range of the voltage required for driving the LCD panel **45**. The gain control signal **25** is a digital signal indicating the desired contrast level of the LCD panel. The scaled digital value of the video signal from the scaling circuit **15** and the gain control signal **25** are the inputs to a multiplier circuit **20**. The gain control signal **25** being a multiplying factor for the scaled digital value of the video signal. The output of the multiplier circuit **20** being the product of the scaled digital value of the video signal and the gain control signal **25** is the input to the adder circuit **30**. The offset control signal **35** is digital value indicating the desired brightness of the LCD panel **45**. The offset control signal is added to the scaled and gain adjusted video signal to provide the desired level of luminance for the LCD panel. This value is really a pointer to a position within the gamma correction mapping table **40** representing the desired luminance of the LCD panel. It is known in the art that the function

42 of the relative luminance of the LCD panel to the drive voltage necessary to achieve the luminance is not linear. Further, providing a "Look-Up" table **40** of entries for this function is requires less computation resources and circuitry than direct calculation of the function. In the "Look-Up" table **40**, the magnitude of the video signal for the desired relative luminance and the corresponding table entry is the value of the drive voltage required for the LCD panel **45** to emit light at the desired luminance.

[0004] The drive level (**Z**) is thus determined by the function:

$$\mathbf{Z} = \mathbf{G_orig}((\mathbf{x} * \mathbf{a}) + \mathbf{b})$$

where:

Z is the magnitude of the voltage necessary to drive the LCD panel **45**.

x is the voltage level of the video signal **40**.

a is the magnitude of the gain control signal **25**.

b is magnitude of the offset signal **35**.

G_orig is the function **42** as mapped in the gamma correction mapping table **45**.

- [0005] Refer now to Fig. 2 for a discussion of the operation of the circuit to adapt the video 5 signal for operation with the LCD panel 45. The digital value of the video signal 5 is applied to the multiplier circuit 20 to generate the scaled values 22 of the video signal. The scaling being the gain value (a). The adder circuit then adds the offset value (b) to generate the mapping values 32. The mapping values 32 act as pointers (Y) to the gamma correction mapping table 40. The values of the gamma function (G_{orig}) as recorded in the gamma correction mapping table 40 are extracted and applied as the drive signal (Z) 44 for the LCD panel 45.
- 10 [0006] The circuitry as described requires a physical multiplier and a physical adder. This adds complexity and consequently cost to a video display system. Further, the additional circuitry impacts performance of the video display system, particularly with higher resolution displays.
- [0007] U. S. Patent 5,796,384 (Kim) describes a gamma correction circuit of a liquid crystal display using a memory device. The gamma correction circuit compensates for the non-linear characteristics of gamma. The gamma correction circuit includes a memory device for storing programmed data. The programmed data is used to make gamma constant and to make the light transmissivity vary linearly with the input image data. The programmed data may be changed according to the characteristics of the liquid crystal being driven.
- 15 20 [0008] U. S. Patent 5,987,167 (Inoue) illustrates a color image display that includes an input color characteristic obtaining unit for obtaining input color

characteristic data simultaneously with input of image data. The display has an input color characteristic data storage unit for storing the obtained input characteristic data. The display includes an image display device such as a CRT. A display color characteristic data storage unit stores the color characteristic of the image display device. A color transformation table generator creates a color transformation table and a color transforming circuit provides the color-transformation of the image data from selected color transformation tables.

[0009] U. S. Patent 6,388,648 (Clifton, et al.) teaches an LCD projection unit.

The LCD projection unit employs a luminance and color balance system. The luminance and color balance system employs an LCD array characterization lookup table that stores multiple sets of luminance and gamma correction values that are user selectable to control luminance and color balance. The lookup table values are determined by measuring the transfer function of the LCD array in the projection unit for each of a set of red ("R"), green ("G"), and blue ("B") input data values. The resulting S-curve responses are converted to corresponding sets of gamma responses and scaling the gamma responses to generate multiple R, G, and B families of luminance and gamma corrected values. Color balance is adjusted by selecting the particular R, G, and B families of luminance and gamma corrected values that cause the LCD projection unit to match a predetermined ratio of R, G, and B luminance values. Luminance is adjusted by selecting sets of families of R, G, and B, luminance values that maintain the color balance ratio while causing the LCD to transmit the desired overall luminance. The primary colors are adjusted by a method of color mixing implemented by a

mathematical matrix algorithm that generates color modification coefficients for a color space conversion circuit. The primary color matching algorithm involves measuring the intrinsic colors coordinates of the primaries, determining a set of predetermined target coordinates, and performing matrix operations to calculate the coefficients used in the color space conversion circuit to convert the measured to the target coordinates, thereby matching the primary colors.

[0010] U. S. Patent 6,271,822 (Chiang) describes a digital LCD driving circuit.

The LCD driving circuit drives an LCD to display video images. The LCD driving circuit includes a digital gamma-correction and inversion circuit for performing a digital gamma-correction process on the digitized video signal and then performing a polarity inversion process on selected lines of the video signal. The digital gamma-correction and inversion circuit is coupled directly to a display memory unit so as to fetch the digitized video signal directly from the display memory unit. A digital-to-analog converter is coupled to the digital gamma-correction and inversion circuit for converting the digital output of the digital gamma-correction and inversion circuit into analog form. Further, the LCD driving circuit comprises an LCD timing control circuit, which is coupled to receive a plurality of video control signals associated with the digitized video signal, for converting the video control signals into an LCD timing control signal to control the LCD to display the video signal. Still further, the LCD driving circuit has a Pulse Width Modulator and shutdown circuit for supplying power to the LCD and shutting down the LCD when the LCD has been idle for a preset period.

Summary of the Invention

[0011] An object of this invention is to provide a display controller for providing luminance values to a display.

[0012] Another object of this invention is to provide a display controller for providing a display controller where values for contrast and brightness for the display are constructed within a gamma correction mapping table.

[0013] To accomplish at least one of these and other objects, a display controller has an original gamma correction mapping table, a gamma correction transform circuit and a transformed gamma correction mapping table. The original gamma correction mapping table contains entries describing a default luminance value to be provided the display for a magnitude of a video input signal.

[0014] The gamma correction transform circuit is in communication with the original gamma correction mapping table to receive the entries and connected to receive a contrast signal and a brightness signal. From the contrast signal and brightness signal, the gamma correction transform circuit transforms the entries to transformed luminance values.

[0015] The transformed gamma correction mapping table is in communication with the gamma correction transform circuit to receive the transformed luminance values. The transformed gamma correction mapping table is further connected to receive a video signal, whereby the magnitude of the video signal provides a pointer to the luminance values to be used to drive the display.

[0016] The gamma correction transform circuit executes the function:

$$G_new(i) = G_orig((i * a) + b)$$

where:

i is a counter representing potential magnitude values of the
video signal,

G_new(i) is the transformed value of the luminance value for
an ith magnitude,

a is a magnitude of the contrast signal, and

b is a magnitude of the brightness signal.

10 [0017] Alternately, the gamma correction transform circuit executes the function:

$$G_new(i) = G_orig(C_i)$$

where:

$$\begin{array}{l|l} C_i = b & i = 0 \\ C_i = C_{i-1} + a & i > 0 \end{array}$$

C_i is a pointing variable to the luminance values in the
original gamma correction mapping table,

i is a counter representing potential magnitude values of the video signal,

a is a magnitude of the contrast signal, and

b is a magnitude of the brightness signal.

5 [0018] In a preferred embodiment of the display controller, the gamma correction transform circuit is a microcontroller and the original gamma correction mapping table and the transformed gamma correction mapping table are stored in a memory connected to the microcontroller. The microcontroller receives the contrast and brightness signals and then generates the transformed gamma
10 correction mapping table from the original gamma correction mapping table and stores the transformed gamma correction mapping table in the memory. The microcontroller then receives the video signal determines the location within the memory containing appropriate luminance value and retrieves the value from the memory and transmits the value to the display.

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Brief Description of the Drawings

[0019] Fig. 1 is a functional block diagram of a display controller of the prior art.

[0020] Fig. 2 is a diagram of the data transformation of the display controller of the prior art.

[0021] Fig. 3 is a functional block diagram of the display controller of this invention.

[0022] Fig. 4 is a diagram of the data transformation of the display controller of a first embodiment of this invention.

5 [0023] Fig. 5 is a diagram of the data transformation of the display controller of a first embodiment of this invention.

[0024] Fig. 6 is a block diagram of a display controller of this invention employing a microcontroller.

[0025] Fig. 7 is process flow diagram for controlling a display employing a
10 gamma correction mapping table.

Detailed Description of the Invention

[0026] In the video control circuit of this invention, the default gamma correction mapping table is transformed by the contrast signal and brightness signal to create a transformed gamma correction mapping table. The video signal is used
15 as the access pointer to access the contents of the transformed gamma correction mapping table. The contents of the transformed gamma correction mapping table represent the magnitude of the voltage that is used to drive the LCD display panel.

[0027] Refer now to Fig. 3 for a detailed description of the video control system of this invention. The video signal **105** is an analog voltage that represents the magnitude of the luminance desired to emanate from the display **145**. The video signal **105** is the input to the analog-to-digital converter **110**. The analog-to-digital converter **110** translates the video signal **105** to a sampled digital data representing the magnitude of the video signal **105**. The digitized video signal that is the output of the analog-to-digital converter **110** is the input to the scaling circuit **115**. The scaling circuit **115** adjusts or normalizes the digital value of the video signal **105** such that the range of the video signal encompasses the range of the voltage required for driving the LCD panel **145**.

[0028] The digitized and scaled video signal **117** is the input to the transformed gamma correction mapping table **120**. The digitized and scaled video signal **117** acts a pointer to the contents of the transformed gamma correction mapping table **120**. The contents of the transformed gamma correction mapping table **120** are the digital values of the magnitude of the voltage to be applied to the LCD panel **145**. The contents of the transformed gamma correction mapping table **122** define function **122** the relative luminance of the LCD panel **145** versus the magnitude of the driving voltage required to create the luminance of the LCD panel **145**.

[0029] The contents of the transformed gamma correction mapping table **120** is further dependent on the magnitude of the gain control signal **125** for the contrast and the offset control signal **135** for the brightness of the LCD panel **145**. The

gain control signal **125** and the offset control signal **135** are inputs to the gamma transform circuit **130**. The gamma transform circuit creates a counting variable (i) that simulates the value magnitude of the video signal and is varied over the range of the digitized and scaled video signal **117**. The gain control signal **125** and the offset control signal **135** are combined to generate a pointer value for the original gamma correction mapping table **140**. The contents of the pointer value are retrieved from the original gamma correction mapping table **140** and placed in the transformed gamma correction mapping table **120** in the location defined by the counting variable (i). The transformed gamma correction mapping table **120** then contains the value of luminance as changed by the gain control signal **125** to adjust the contrast and the offset control signal **135** to adjust the brightness of the LCD panel **145**.

[0030] Fig. 4 provides an illustration of the data flow and operation of the display control system of this invention. The gamma transformation circuit has a count generator **132** that creates the counting variable (i). The gamma transform circuit **130** performs the multiply of the gain control signal **125** by each of the count variables (i) and then performs the addition to the offset control signal **135** to generate a pointer **134** to the location of the function **142** that defines the relative luminance versus the relative input voltage for the LCD panel **145**. The contents of the original gamma correction mapping table **140** are transferred as the transformed gamma correction values **124** to the transformed gamma correction table **120**.

[0031] The gamma correction transform circuit **130** the function **142** as shown above can be expressed as:

$$G_new(i) = G_orig((i * a) + b)$$

where:

5 i is the counting variable **132** representing potential magnitude values of the video signal,

$G_new(i)$ is the transformed value of the luminance value for an i th magnitude,

a is a magnitude of the gain control signal **125**, and

10 b is a magnitude of the offset control signal **135**.

[0032] The calculation of the transformed gamma correction values occurs only with each change of the gain control signal **125** and the offset control signal **135**. During operation the digitized and scaled input video signal **117** becomes the pointer to the locations of the transformed gamma correction mapping table **120**.
15 The locations pointed to by the and scaled input video signal **117** are transferred as the drive signal **144** to the LCD panel **145** for display.

[0033] An alternate embodiment of the data flow and operation of the gamma transform circuit is shown in Fig. 5. In the first embodiment of this invention as described above, the gain control signal **125** is multiplied by the counter variable

(i). In physical implementations, this requires complex multiplier circuits that require circuit excessive area to implement and consume a large amount of time. In the second embodiment, the function of the gamma transform circuit **130** is implemented as an adder. The gamma transform circuit **130** has the count generator **132** to generate the counting variable (**i**). The counting variable is transferred to the adder transform circuit **137** to generate the pointer values (**Y**) for the transformation. The adder transform circuit **137** receives the gain control signal **125** and the offset control signal **135** for the transformation. The transformation has the first counting variable **132** value (**i=0**) set to the value of the offset control signal **135** (in this example **b=1**). For each succeeding counting variable **132** value, the pointer value (**Y**) is equal to the previous pointer value added with the gain control signal **125** value (in this example **a=2**). The calculated pointer value is assigned a variable **C_i** and the transformed luminance values are calculated according to the function:

$$G_new(i) = G_orig(C_i)$$

where:

$$\begin{array}{l|l} C_i = b & i = 0 \\ C_i = C_{i-1} + a & i > 0 \end{array}$$

C_i is a calculated variable pointing to the luminance values in the original gamma correction mapping table,

i is the counting variable **132** representing potential
magnitude values of the video signal,

a is a magnitude of the gain control signal **125**, and

b is a magnitude of the offset control signal **135**.

5 [0034] The calculated pointer (**C_i**) is the pointer value to the original gamma
correction mapping table **140** and the gamma correction values **142** are
extracted to form the transformed gamma correction values (**G_{NEW}**) **124**. The
transformed gamma correction values are then stored to the transformed gamma
correction table **120**. The digitized and scaled video signal **117** is applied as the
10 pointers to the transformed gamma correction table **120** to generate the drive
signal **117** for the LCD panel **145**.

[0035] If the gain control signal **125** and/or the offset control signal **135** are set to
the values of the default or original gamma correction mapping table **140**. The
transformed gamma correction mapping table **120** receives the non-transformed
15 values of the luminance or the original gamma correction mapping table is used
directly to receive the digitized and scaled video signal **117** and provide the
luminance values. Either alternative is in keeping with the intent of this invention.

[0036] The gamma transform circuit **130** as described may be circuitry
implemented as an integrated circuit have the multipliers or adders as described
20 in the function of the circuit. However, a small microcontroller provides a cost
effective alternative to the application specific design as described. A

microcontroller, as is known in the art is a highly integrated chip that contains all the components comprising a computer controller. Typically this includes a central processing unit, random access memory, some form of read only memory, input/output ports, and timers. Referring now to Fig. 6 for a discussion of the implementation of the video control system with a microcontroller **200**. The video signal **105**, as described above, is an analog signal representing the value of luminance required to emanate from the LCD panel **145**. The video signal **105** is applied to analog-to-digital converter **110** to create the sampled digitized video signal **117**. In this case the scaling of the digitized video signal occurs within the microcontroller.

[0037] The gain control signal **125** and the offset control signal **135** are now digital data word respectively having **m** bits and **n** bits. The gain control signal **125** and the offset control signal **135** are applied to the microcontroller **200**. The microcontroller **200** is connected to (or has included within the integrated circuit) the memory **205**. The memory **205** contains the program code that is executed to provide the luminance values **144** dependent on the values of the digitized video signal **117**, the gain control signal **125**, and the offset control signal **135**. Further, the memory **205** contains the original gamma correction mapping table and the transformed gamma correction mapping table.

[0038] As is known, the microcontroller has addition instructions and often multiply instructions and can thus implement the functions of the display control system as described in Figs. 3-5. Often, instructions such as multiply are too

complex for the microcontroller to execute in the desired time. An alternative to direct multiplication is a table-lookup where the operands act to pointers to locations within a table. The location within the table contains the resultant from the function performed on the operands. In the case of the gamma transform circuit **130**, the implementation of the calculation of the variable pointing to the luminance values in the original gamma correction mapping table are the contents of a table resident within the memory **205**. The gain control signal **125** and the offset control signal **135** are combined to calculate the address of the position within the table containing the value of the pointing variable. An alternative for the pointing variable is using the gain control signal **125** and the offset control signal **135** combined to create the address of the gamma correction values **142** rather than creating the pointing variable and then using the pointing variable to access the gamma correction values **142**. The use of the calculation of the pointing variable by the gamma transform circuit **130** versus direct access of a table within the memory **205** becomes a tradeoff between the performance of the microcontroller **200** and the quantity of the memory **205**.

[0039] The luminance signal **144** in this implementation is digital data transferred from the microcontroller **200** to the digital-to-analog converter **210**. The digital-to-analog converter **200** provides an analog voltage that has an amplitude that is represented by the luminance signal **144**. This voltage is value necessary to drive the LCD panel **145**.

[0040] Refer to Fig. 7 for a description of a method for transforming gamma correction values of luminance for contrast and brightness. The method described hereinafter maybe implemented as a program for the microcontroller of Fig. 6. The program being stored in the memory as described. The memory for the program maybe random access memory or read only memory. Alternately, the memory may be magnetic storage devices or optical storage devices. Normally, microcontroller systems have the memory implemented as the random access memory or the read only memory, since these controllers are part of an embedded system and having a magnetic or optical storage devices consume too much space and are too costly.

[0041] The method begins with the reception of the gain control signal (Box **300**) describing the contrast function of the display and the offset control signal (Box **305**) describing the brightness function of the display. The received gain control signal is compared to the default gain control value (Box **310**) and the offset control signal is compared to the default offset control value (Box **315**). If the gain control signal and the offset control signal are equal to their default values, the transformed gamma correction mapping table **330** is set (Box **320**) to the value original gamma correction table **325**. This can be accomplished by literally copying the original gamma correction mapping table **325** to the transformed gamma correction mapping table **330** with no transform or by setting a pointer such that the original gamma correction mapping table **325** is used for the providing the luminance values.

[0042] If the gain control signal and/or the offset control signal are not equal to the default gain and offset values, the luminance values of the original gamma correction mapping table **325** are mapped (Box **335**) to the transformed gamma correction mapping table **330**. The input video signal is used as a pointer (Box **340**) to select the luminance values in the transformed gamma correction table **330**. The luminance values from the transformed gamma correction table **330** are transferred (Box **345**) to the display.

[0043] The mapping (Box **335**) of the values of the original gamma correction mapping table **325** to the transformed gamma correction mapping table **330** is as shown in Figs. 4 or 5. Fig. 4 showing the mapping direct mapping employing the multiply function. Even in modern microcontroller integrated circuits, the multiply function requires excess resources and consumes an inordinate amount of time. The mapping of Fig. 5 employs a simple addition, which requires less resources and time and allows the use of a much simpler microcontroller.

[0044] While this invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.

[0045] The invention claimed is: